Decision support system for collaborative freight transportation management: a tool for mixing traditional and green logistics.

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Guido Perboli[1,2], Mariangela Rosano[2], Luca Gobbato[2]

[1] CIRRELT, Montreal, Canada
[2] DAUIN, Politecnico di Torino, Turin, Italy
{guido.perboli@polito.it, mariangela.rosano@polito.it, luca.gobbato@polito.it}

Abstract. In recent years, freight transportation emerged as a key factor in the development and dynamicity of countries, although it has a considerably impact on urban areas, due to the environmental issues. In this context, several stakeholders have implemented City Logistics solutions in order to make transportation more sustainable and efficient. This paper proposes a case study concerning the collaborative transportation system involving traditional and green couriers, in the city of Turin. This freight pooling is supported by a decision support system that combines the ERP "Odoo" with an algorithm for the optimization planning of routes. This decision support system is described in the second section and finally, some results obtained from its application are discussed.

Keywords: Collaborative freight transportation, freight pooling, City Logistics, green logistics.

1 Introduction

In recent years, freight transportation emerged as a crucial factor in the development of countries, allowing occupation, companies' procurement, social welfare, as well as economical dynamicity and global growth. According to the statistics proposed by [1], to an efficient transportation of passengers and goods, it is connected an increase of Gross Domestic Products (GDP) in countries of the European Union. Social phenomena as the urbanization, the demography growth and the change of customer behavior due to the diffusion of smart and green lifestyles, combined with those related to the company process, such as the adoption of new manufacturing philosophy (e.g., Just in Time), have introduced new complexities and dynamics in the transportation system.
This is also affected by e-commerce that led an increase of the urban freight transportation demand and a mutation of its patterns. The term urban freight transportation demand defines all the activities of parcels pick up and delivery, as well as the flow generated by the reverse logistics, which take place in urban areas. This demand is more fragmentary, because composed by frequent orders of individual small and medium sized parcels. Although freight transportation activities ensure the dynamicity of urban centers, they have a considerably impact on environment, due to the negative externalities generated, such as the increase of traffic and congestion, the energy consumption, the visual, noise and air pollution. In fact, the transportation sector is responsible for the production of a large amount of greenhouse gas (GHG) and other pollutants (e.g., PM_{10}, $PM_{2,5}$, NO_x). In particular, the CO2 emissions from transportation account for about 23.7% of total CO2 emissions in Europe [1].
These problems make the last mile the more expensive, least efficient and most polluting sections of the entire logistics chain [2]. According to the analytics provided by the United Nations, these inefficiencies of transport network cost globally between 1 and 2 trillion dollars per year [3].
In this scenario, it arises the awareness of the need to make the urban mobility more sustainable and competitive, in order to support the growth of Smart Cities. In this direction, several stakeholders, as local administrations, individuals and companies operating in Courier, Express and Parcel market (CEP) are developing City Logistics solutions, also in fulfillment of the European Commission disposals proposed in the program "Horizon 2020".
The literature provides an exhaustive description of the main measures implemented ([4], [5], [6]), although we explore the subject related to the adoption of green vehicles with low environmental impact. This solution is an innovative framework identified by the European Commission, as one of the priority societal challenges, called "Smart, Green and Integrated Transport", under the Horizon 2020 Work Programme 2014-2015 [7].

Differently to the past, in recent years, companies overcome the idea of the presence of a trade-off between the economical efficiency and effectiveness of transportation activities and their environmental respect. In fact, companies recognize the value added of green solutions as source of competitive advantage. The economical efficiency of these solutions is guaranteed by collaborative strategies in urban freight transport system. According to [8], [9], and [10], different stakeholders of urban logistics can make collaborative agreements to improve the efficiency and then reduce the overall costs of the global supply chain activities network.

Focusing on manufacturers, shippers and logistics service providers, [11] recognize that the main objective of the synchronized last mile collaborative urban logistics paradigm is the improvement of their economies of scale/scope in terms of value chain efficiency (total end-to-end logistics cost), overall system productivity and effectiveness (of asset utilization and customer service levels), harmonized data analysis and environmental sustainability (minimize the overall carbon footprint) without compromising their competitive advantage.

This paper deals with these issues, presenting the results of a case study of the collaboration between couriers operating in last mile segments in the city of Turin. In particular, our solution mixes the traditional business model proposed by courier that used fossil-fuelled vans, with those proposed by green courier using bike.

Relating to this last type of operator, we have considered an Italian company called PonyZero S.r.l., born in the 2012 from the idea to become the first bike messenger in Turin.

Under its business model, this firm proposes to offer bike-logistics services and in particular time-sensitive parcel deliveries in the last mile segment, using bike and cargo bike. This value proposition gives some benefits to the customer segments, represented by the traditional express courier, as TNT Italy. On the one hand, these consist in the costs and efficiency optimization, overcoming the complexities that involve distribution activities in urban areas (e.g., mobility restrictions, LTZ areas, inadequate or insufficiently available infrastructure, limited usability of loading and unloading zones). On the other hand, in the achievement of a “green image” and green credentials required for the creation of a sustainable supply chain. These benefits reinforce the relationship that the two types of couriers, establish in the collaborative transportation field, sharing their efforts, knowledge and material resources to execute the parcel delivery activities in urban areas.

[9] proposed a classification of the resources shared between several stakeholders, which are involved in the collaborative agreement. According to them, we can define the collaborative transportation approach adopted in the case study presented, as a freight pooling. This term means to give the freight to another transportation carrier that will visit the final destination of this freight, in order to overall reduce the loading rates of the vehicles [9].

According to [12] in supply chain management, collaboration occurs at several stages of the chain and with different levels of interaction. In particular, PonyZero S.r.l and TNT Italy are involved in a collaborative sharing with hierarchical decision-making. In fact, they commonly manage the freight, but each part individually takes its operational and tactical decisions, and those strategic are hierarchic.

The nature “multi-actor” and “multi-modality” of the system analyzed, requires a decision support system (DSS), capable to drive the implementation of an urban freight transportation management strategy and consequently the decisions of each stakeholder.

In the case of study, this DSS consists of an Enterprise Resource Planning software (ERP), known as “Odoo” [13], which is integrated with an algorithm for the optimization and the planning of fleet usage and routes, optimizing the total delivery time and the traveled distances. Differently from similar applications, the optimization has to consider specific issues as the balancing of the routes, the specific constraints related to cargo bikes and the green aspects of the problem.

This DSS combined with the innovative business model based on the use of a green vehicle par excellence as the bike, permits at PonyZero S.r.l., to obtain a competitive advantage that limits the repeatability of such model. The DSS has also the important capability to converge the system towards a state of equilibrium between traditional transportation model and green model, permitting their coexistence in urban areas.

The paper is organized as follows. Section 2 gives an overview of the ICT infrastructure Odoo and highlights the algorithm using for the optimization, while the results of the application of this DSS are illustrated in Section 3.

2 The ICT Infrastructure "Odoo"

Through the collaboration with TNT Italy, PonyZero S.r.l. obtains the critical mass to sustain its business model. At the same time the higher number of final customers to serve increases the complexities on the last mile segment. In fact, the increased volume of freight requires to fulfill time-sensitive delivery requirements, such as time windows to respect, repeated delivery because consumer is not at home, reverse logistics flows or real-time anomalies.
These criticalities make necessary an information technology support that automatizes and optimizes the whole operative and decisional process.
In this case study, the DSS abovementioned has been developed by the ICE (ICT for City logistics and Enterprises) laboratory of the Department of Control and Computer Engineering of the Politecnico di Torino, which provided the software and the integrated optimization algorithm for the trips creation, also in collaboration with other technological partners. During the development of the DSS, it emerged the need to integrate the functionalities required in the urban freight collaborative transportation, into an existing framework. After considering various options, we have chosen the open-source ERP Odoo, known formerly as "OpenERP".
Odoo is a web-based software with a three-tier architecture, respectively the database server Postgres, the application server, written in Python language, and the Javascript application. Like many ERPs, it has a modular structure.
The following advantages led the choice of using Odoo as development platform:

- Customer orientation. It is focused on the clients' management and on the design of operative workflows. Also, it offers useful integrated functions as the creation of reports.
- Highly customizable. The modules can be easily created or modified according to the current needs.
- Lean and efficient. It is possible to install only the modules with the needed functionalities, making it as light and more performing as possible.

Despite the dimension of the Odoo community of developers, due to the singularity of the workflow to emulate, we have not found any existing module capable to satisfy the requirements of our benchmark context, where Pony Zero S.r.l. operates.
Thus, we have created anew these modules, described below in their main features and the resulting workflow.

All the functionalities associated to the customers, such as the clients view, their import, the addresses management, the packages validation and the routes planning are contained in the "*parcel_import*" module. Conversely, the "*parcel_trips*" module handles the trips management, the biker selection and the trip start and stop.

The key steps of the automatized workflow, illustrated in the Figure 1, are following described:

1. Clients import
2. Clients management
3. Trips creation
4. Trips management
5. Delivery

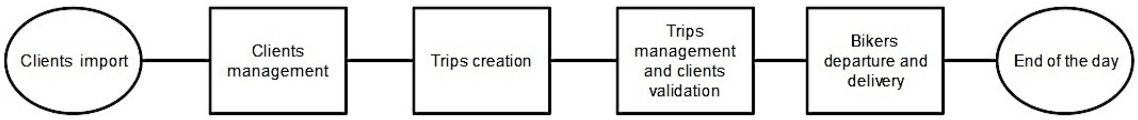

Figure 1: Workflow of the Decision Support System.

Clients import
Clients import is managed by a wizard that loads the data in the database for the selected day. By default, the date is the current, but it is possible to plan future clients and trips. The data are provided by the supplier at the packages, including address, barcode, as well as restrictions of the time windows due to delivery options.

Clients management

Once the clients have been loaded into the database, their address must be geolocalized in order to retrieve the geographic coordinates, which are used by the algorithm to subsequently plan the routes. Due to the relatively low number of clients, it has been chosen to use Google Maps and navigation API [14]. This service takes a complete address (composed by address, city and nation) in input as a string, and returns a Json output containing a list of all the references found in Google's database, along with additional information describing the quality of the match. Depending on the correctness of the address, the geolocalization can have a positive or a negative outcome. In particular, a client will be set as an anomaly if its geolocalization returns a partial match, multiple results or no results at all. These anomalies must be corrected manually, and the ones for which this is not possible remain in the warehouse and are not delivered.

Trips creation

The wizard for the routes planning takes several parameters in input, making the process flexible enough to withstand different situations (e.g., different number of available bikers, different cargo dimensions, etc…). These parameters are the number of bikers, the departure hour, the maximum duration of the trip, and the maximum number of packages for biker. The clients and the chosen settings are given to an external algorithm that optimize the planning of routes and dispatchers. The proposed algorithm is a Large Neighborhood Search method based on the original work by Ropke and Pisinger [15]. It implements a Vehicle Routing Problem with Time Windows (VRPTW). In fact, the existing time slots make indeed this problem a VRPTW, and the number of trips' settings made it necessary to have an underlying flexible algorithm capable of handling multiple configurations. Additional constraints are related to technical restrictions due to the usage of the bikes, the possibility to fix the number of routes and to balance the routes in terms workload. In more detail, after building an initial solution by a best insertion algorithm, the heuristic iteratively chooses a removal heuristic R, removes q customers from the routes in the current solution by applying R and reinserts the previously removed customers in the existing routes. If the new solution is better than the best one found so far, the new solution is accepted as both new best and new current solution. On the contrary, if it is not better, the new solution becomes the current solution according to the greedy acceptance defined in [16].

We implement three removal heuristics:

- random removal: q customers are chosen randomly;
- radial ruin: given a customer c^* , a percentage chosen at random on the total number of customers equal to $\alpha = 0.5$ is removed. The customers are the ones nearest to c^*according to the distance matrix;
- small radial ruin: as in radial ruin, but with $\alpha = 0.3$.

The removal heuristics are chosen by a roulette wheel algorithm, where the probability of each heuristic is set to 0.2, 0.4 and 0.6, respectively. The insertion heuristic implies a standard regret insertion. In order to increase its portability in Cloud-based environments, the algorithm was implemented in Java.

The algorithm returns the routes, creates a trip for each route and links the associated clients to it in a 1:N configuration. The whole process is completely transparent to the user, and takes few minutes to be carried out, depending on the settings and the number of clients. Notice that concerning the green aspects, the gains in terms of CO2 are computed for each trip according to a methodology based on the ISO/TS 14067 document. This methodology considers not only the CO2 gain directly related to the substitution of a traditional vehicle, but also the CO2 equivalent due to the whole chain of the traditional vehicles, including the gasoline production.

Trips management and loading

From the trip view it is possible to select the biker, visualize the route on a map (Figure 2) and print its deliveries list. It is also possible to change manually the order of the deliveries and to change the trip's status. To start a trip, it is first necessary to validate all of its clients. This action is needed in order to check if all the associated packages are whole and there are no packages left out from the borderaux. The wizard handling the validation process is implemented in such a way to optimize the whole activity, so that even with a large number of packages needs a short time to be validated. In particular, at each barcode scan the relative package is validated and it is shown the id of the associated trip, so that it can be immediately put in the right cargo. In this way, at the end of the validation process the bikes are already filled and ready to go.

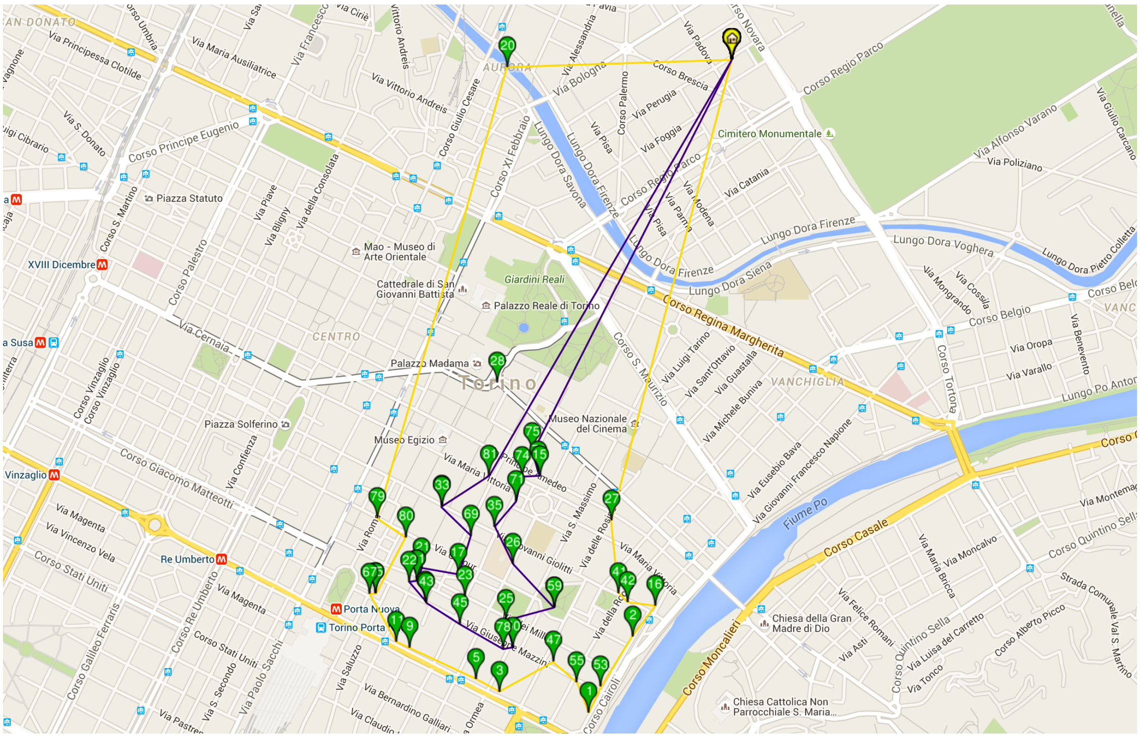

Figure 2: Example of trip view generated by the application.

Delivery
During the delivery activity, bikers change the clients' status by using a mobile application directly connected to the software's backend. In such a way, it is possible to check on the trip's progress in real time. Also at the end of the day, when all the bikers have returned, it is not necessary to check manually if all the clients have been set as delivered or anomalies, as the software provides a set of real time statistics implemented directly as a view on the database. The delivery module is also connected by means of Json APIs to a mobile application installed in the smartphones of the bikes.

3 Results

The DSS represents for PonyZero S.r.l. a strength improving its performance, flexibility and operative efficiency. In fact, the lower time needed to execute the steps 1-4 of the workflow allows to explain the delivery activities in just few minutes from the moment when the goods arrived at PonyZero S.r.l. warehouse. This aspect, combined with the optimization planning of trips, guaranteed by the algorithm, and the use of the bikes, more performing in traffic conditions, permits to reach the customers in a less delivery time.
Consequently, from the firm point of view, the probability of delivery failure decreases, reducing the additional costs for a second time delivery, and the number of packages delivered every day potentially increases, with benefits in terms of revenues.
Also from the customers' point of view, the respect of time constrains, increases the quality level perceived. The collaborative freight transportation between traditional and green couriers generates benefits relating to the environmental impact. As emerged in [17], serving a greater part of the urban freight transportation demand, using green vehicles (bikes and cargo bikes) permits to obtain CO2 savings.
Table 1 reports some realistic simulations. The parcel data are obtained according to a realistic distribution in the City of Turin, coming from the URBan Electronic LOGistics (URBeLOG) project [18]. The instances ranges from 1000 to 4000 parcels and are provided by a large parcel delivery company. In the simulations, we consider the assignment of the deliveries to each type of courier, according to several factors as follows:

- **Geographical extension**. The area of the analysis consists of the town center plus the semi-central area, composed by a part of surrounding neighborhoods directly reachable by bikes.

- **Classes of parcels**. [19] defines with the general terms of "parcels", boxes with a weight less than 30 kg manageable by a single person. However, considering only the deliveries in this area, we have classified the parcels similar to the categorization proposed by [18] that distinguish into letters, small and large parcels. Based on this classification, we have considered three different segments, filtering the parcels using their weight: 0-3 kg, 3-5 kg and more than 5 kg.
- **Capacity of vehicles**. Vans have a maximum capacity of 700 kg. While, the green couriers use messenger bags with a capacity of 20 kg, when they have to manage parcels up to 3 kg, or combined with the cargo bikes that contain up to 50 kg, for weightier loads.

According to these dimensions, we consider the use of bikes to deliver the parcels 0-3 kg and 3-5 kg, in the center and semi-central area. While the traditional courier can handle the parcels with a weight exceeding the 5 kg in the focus area and any class of parcels in the rest of the city, difficult to reach by bikes.

The results of a simulation analysis conducted shows as a higher reduction of CO2 emission is measured when traditional courier outsources the parcels with a weight between 3 to 5 kg. In particular, this segment implies long distances traveled, due to the saturation of the vans that forced a repeated return on the distribution center. On the contrary, the outsourcing lead to a reduction of the number of vans on the road and a consequent reduction of the distances traveled. In fact, as highlighted in the Table 1, when bikers deliver the parcels 0-3 kg and 3-5 kg, the distance traveled by traditional courier decreases in mean of about 26% in semi-central area and 25% in center, with consequent reduction of its environmental impact and its operating kilometric costs. However, in this paper, we do not analyze in detail the impact on costs, because it overcomes the scope of this work. While, notice how assigning the parcels 0-5 kg to the bikes can bring to a reduction of emissions up to 14 tons of CO2 per year in a medium sized city as Turin.

Table 1: Results of the simulation analysis.

Instances	Number of parcel weight served by the green courier	CO2 savings per day [kg]		Δ Distance traveled by traditional courier [%]		Deliveries per hour for green courier [%]	
		Semi-Centre	Centre	Semi-Centre	Centre	Semi-Centre	Centre
Instance 1	0-3 kg	33.68	21.69	- 22%	- 24%	71.83%	76.40%
Instance 2	0-3 kg	33.86	15.63	- 18%	- 15%	70.17%	73.59%
Instance 3	0-3 kg	40.91	25.61	- 22%	- 17%	72.14%	74.00%
Instance 1	0-3 kg and 3-5 kg	45.24	26.89	- 29%	- 30%	76.32%	79.80%
Instance 2	0-3 kg and 3-5 kg	43.95	25.53	- 24%	- 24%	74.52%	76.54%
Instance 3	0-3 kg and 3-5 kg	47.88	19.71	- 26%	- 21%	77.84%	78.68%

In conclusion, the reduced number of vehicles fossil fuelled on the road, combined with the optimization of the bikers' routes, permits on the one hand to obtain environmental benefits in urban areas, as already discussed. On the other hand, to maintain the high quality level that characterized the time-sensitive delivery services, as showed by the high ratio of deliveries per hour obtained by the green courier.

Regarding the Odoo framework and the integration with the optimization part, the main problems were due to the need of mapping and integrating the parcel delivery workflow in the Odoo one. In particular, specific issues were related to the interaction between Odoo, Google APIs and the Java VRPTW optimizer. Generally speaking, after a quite steep initial learning curve, due to the lack of documentation concerning the Odoo version 8.0 at the beginning of our project (moving from Odoo 7.0 to Odoo 8.0, the ERP framework was heavily changed by the Odoo team), the advantage of using a standard open framework in order to wrap the optimization tools proved its efficacy. In fact, the integration with accounting and CRM, as well as the reporting tasks had a considerable speed-up. Moreover, having Odoo as basis of our solution, let us to move it to the Amazon Cloud in a short time, by reducing the ICT maintenance costs of the PonyZero S.r.l. company. In fact, the trip optimizer requires the availability of a large amount of computational power only for a limited time slot (usually early in the morning) and the cloud-based deployment let them to dynamically change the effort, according to their real needs.

4 Conclusions

Collaborative freight transportation is an emerging solution to reduce the inefficiencies of the last mile distribution. In this paper, we presented a case study of a collaborative sharing approach involving TNT Italy and the Italian firm PonyZero S.r.l., with the aim to make urban good movement more efficient, competitive and sustainable.
This agreement combines traditional transportation using vans, with green manner, using bike, to overcome complexities of urban areas and the environmental issue.
Then, we described a decision support system developed to support the logistics decision makers in both the optimal planning of routes and dispatchers, and the efficient information sharing. We formulated some considerations concerning the benefits that the DSS provides to PonyZero S.r.l., improving the efficiency and performance of its operations. Finally, we illustrated some results highlighting as the DSS combined with the use of bike in urban areas, generates environmental benefits, in terms of reduction in CO2 emissions.
The future direction of this work concerns the extension of the DSS for the pickup and delivery service, that PonyZero S.r.l. is going to provide to its customers. This service will be characterized by Time Windows as well as priority. In particular, the customers can book the pickup of a parcel, while PonyZero S.r.l. will ensure the delivery in the same day.

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